Lead Screw Application

Load weight = 1000 lb
Lead screw diameter = 1.0 inch
Lead screw pitch = 5 thread per inch
Lead screw length = 48 inch
Slide friction force = 6 ounces (est.)

Step #1

1. Establish Motion Objectives (most Important!):
   - Maximum velocity = 0.15 ft/sec
   - Acceleration time = 0.1 sec
   - Operate at max velocity for 2 sec
   - Deceleration time = 0.1 sec
   - Immediately reverse operation
   - Operate continuously

Step #1a

1. a. Calculate Critical Move Parameters:
   - Max. move speed $\omega_{\text{max}}$?
     $\omega_{\text{max}} = \left( 0.15 \text{ ft/sec} \right) \left( \frac{12 \text{ in}}{1 \text{ ft}} \right) \left( \frac{5 \text{ rev}}{1 \text{ in}} \right) \left( \frac{2\pi \text{ rad}}{1 \text{ rev}} \right) = 56.5 \frac{\text{ rad}}{\text{ sec}}$
   - Max. accel rate $\alpha$?
     $\alpha = \frac{\omega_{\text{max}}}{t_{\text{accel}}} = \frac{56.5 \frac{\text{ rad}}{\text{ sec}}}{0.1 \text{ sec}} = 565 \frac{\text{ rad}}{\text{ sec}^2}$

Step #2a

2. a. Calculate inertia of all moving components
   - $J_M$: when motor is selected
   - $J_C$: shaft coupling - assume zero
   - $J_S$: lead screw shaft ???
   - $J_{L\rightarrow M}$: compute from formula in notes
Lead Screw Shaft Inertia

\[ J_L = \frac{\pi LD^4}{2g} = \frac{\pi (48in \times 0.283 lb/in^2) \times 0.5in)^4}{2 \left( \frac{32 \frac{ft}{sec^2}}{1 \frac{ft}{1fr}} \right)} \]

\[ J_L = .0035 \text{ lb-in-sec}^2 = .055 \text{ oz-in-sec}^2 \]

Load Inertia “Reflected” to Motor

\[ J_{L-M} = \left( W + W' \right) x \frac{a}{2\pi F_S} \]

Assume \( e = 1 \)

\[ 2\pi \frac{rad}{1rev} \]

\[ 5 \text{ rev} \]

\[ 1 \text{ inch} \]

\[ J_{L-M} = 0.0026 \text{ lb-in-sec}^2 = 0.042 \text{ oz-in-sec}^2 \]

\[ J_{\text{total}} = J_M + J_{L-M} = 0.0061 \text{ lb-in-sec}^2 = 0.097 \text{ oz-in-sec}^2 \]

Step #3 & #4

3. Calculate Acceleration Torque at motor shaft due to reflected inertia (load & mechanism only)

\[ \tau_{\text{acc}} = 3.43 \text{ lb-in} = 54.8 \text{ oz-in} \]

4. Calculate all non-inertial forces, torques

- Friction? Pre-loads?
  \[ F_g = (W + W') \times \sin \theta \]
  \[ F_n = \mu \times (W + W') \times \cos \theta \]
  \[ \tau_{L-M} = \frac{(F_p + F_r + F_a)}{2\pi \times F_g \times \theta} \]
  \[ \tau_{\text{total}} = \tau_{L-M} + \tau_{\text{acc}} \]

Step #5

5. Calculate Total Torque reflected to motor

- Peak torque for worst case move
  - Friction torque = 0.2 oz-in
  - Acceleration torque = 54.8 oz-in
- RMS torque for entire move cycle

\[ \tau_{\text{RMS}} = \sqrt{\left(55 \text{ oz-in}^2 \times 0.1 \text{ sec}\right) + \left(0.2 \text{ oz-in}^2 \times 2.0 \text{ sec}\right) + \left(-54.6 \text{ oz-in}^2 \times 0.1 \text{ sec}\right)} \]

\[ \tau_{\text{RMS}} = 16.5 \text{ oz-in} = 1.03 \text{ in-lb} \]
Step #6

6. Make (initial) motor/drive selection
   • Torque available must exceed peak and RMS
     • Remember, motor inertia hasn’t been added
   • Initially select #GNM3125 motor:
     • Stall torque = 68 oz-in
     • No-load speed = 4643 RPM

Step #6 & #7

7. Calculate Torque added by motor inertia
   • J_M = 0.0025 oz-in-sec^2
   • τ_{max} = 56.2 oz-in
   • τ_{RMS} = 17 oz-in

Step #8

8. Torque Available exceeds Torque Required?

Step #8a & #8b

8a. Calculate power dissipated in the motor windings
   • i_{RMS} = τ_{RMS} K_a = 2.5 amp
   • P = R_a i_{RMS}^2 = 9.7 watt

8b. Check temperature rise based on thermal properties
   \[ T = P \left( \frac{R_{th}}{\text{watt}} \right) = 9.7 \text{ watt} \left( 4.3 \frac{^\circ \text{C}}{\text{watt}} \right) = 42^\circ \text{C} \]
   \[ T_{motor} = T_{ambient} + \Delta T = 22^\circ \text{C} + 42^\circ \text{C} = 64^\circ \text{C} \]
   Well below 100 \degree \text{C max}